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# Potential of *Bacillus aryabhattai* to Promote Plant Growth and Mitigate the Effects of Water Deficit

# Potencial de *Bacillus aryabhattai* na promoção do crescimento vegetal e mitigação dos efeitos do déficit hídrico

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## ABSTRACT

Water deficit is one of the main factors limiting soybean productivity, impairing plant growth and reducing crop yield potential. In this context, the use of plant growth-promoting rhizobacteria (PGPR) has emerged as a promising strategy to enhance plant tolerance to abiotic stresses and improve crop development. This study aimed to evaluate the effects of soybean seed inoculation with *Bacillus aryabhattai* on seed seed physiological performance during germination and plant growth under water-deficit conditions. Two experiments were conducted. In the first experiment, a completely randomized design was adopted in a 2 × 2 factorial arrangement, evaluating seed inoculation (with or without *B. aryabhattai*) and water availability (with or without water deficit). Shoot and root length, as well as shoot and root

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fresh and dry biomass, were determined. In the second experiment, the seed physiological performance during germination of inoculated and non-inoculated seeds was evaluated by assessing seedling biomass accumulation. Seed inoculation significantly promoted shoot and root growth under both well-watered and water-deficit conditions. Inoculated plants subjected to water restriction exhibited greater length and biomass accumulation than non-inoculated plants, demonstrating enhanced tolerance to drought stress. In addition, inoculation increased shoot biomass accumulation during the seedling stage, indicating greater early vigor. Overall, the results demonstrate that *Bacillus aryabhattai* has considerable potential as a soybean seed inoculant, promoting plant growth and contributing to improved crop resilience under water-deficit conditions.

**Keywords:** *Bacillus aryabhattai*; *Glycine max*; plant growth-promoting rhizobacteria; drought stress; seed treatment.

**RESUMO**

O déficit hídrico constitui um dos principais fatores limitantes da produtividade da soja, comprometendo o crescimento vegetal e reduzindo o potencial produtivo da cultura. Nesse contexto, o uso de rizobactérias promotoras de crescimento de plantas (RPCPs) surge como uma estratégia promissora para aumentar a tolerância das plantas aos estresses abióticos e favorecer seu desenvolvimento. O objetivo deste estudo foi avaliar os efeitos da inoculação de sementes com *Bacillus aryabhattai* sobre a qualidade fisiológica de sementes e o desenvolvimento de plantas de soja submetidas ao déficit hídrico. Foram conduzidos dois experimentos. No primeiro, utilizou-se delineamento inteiramente casualizado em esquema fatorial 2 × 2, avaliando a inoculação de sementes (com e sem *B. aryabhattai*) e a disponibilidade hídrica (com e sem déficit). Foram determinados o comprimento, a massa verde e a massa seca da parte aérea e do sistema radicular. No segundo experimento, avaliou-se a qualidade fisiológica das sementes inoculadas e não inoculadas por meio da determinação da biomassa das plântulas. A inoculação promoveu incrementos significativos no crescimento da parte aérea e do sistema radicular, tanto em condições de irrigação adequada quanto sob déficit hídrico. Plantas inoculadas submetidas à restrição hídrica apresentaram maior comprimento e maior acúmulo de biomassa em comparação às plantas não inoculadas, evidenciando maior tolerância ao estresse hídrico. Além disso, a inoculação favoreceu o acúmulo de biomassa da parte aérea das plântulas, indicando maior vigor inicial. Os resultados demonstram que *Bacillus aryabhattai* apresenta elevado potencial como inoculante para o tratamento de sementes de soja, promovendo o crescimento vegetal e contribuindo para aumentar a resiliência da cultura em condições de deficiência hídrica.

**Palavras-chave:** *Bacillus aryabhattai*; *Glycine max*; rizobactéria promotora de crescimento; estresse hídrico; tratamento de sementes.

## 1. INTRODUCTION

Soybean (*Glycine max* L. Merrill) is one of the world's most important agricultural crops, playing a strategic role in food security, plant protein production, and the supply of raw materials for several industrial sectors. Soybean grains have high nutritional value, containing approximately 40% protein and 20% oil, making

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this crop essential for both human consumption and animal nutrition. The main product obtained from soybean processing is soybean meal, which is widely used in animal feed production and represents one of the main pillars of the global meat and dairy industries (SEDIYAMA, 2014; HIRAKURI; LAZZAROTTO, 2014).

Within Brazilian agriculture, soybean is the most economically important crop, accounting for the largest cultivated area and the highest production volume among annual crops. In addition to its significant contribution to the national trade balance, soybean cultivation drives several sectors of the agribusiness chain, establishing Brazil as one of the world's leading soybean producers (CONAB, 2017). According to Embrapa Soybean (2021), global soybean production reached approximately 362.9 million tons cultivated over 127.8 million hectares, with Brazil ranking as the world's largest producer, harvesting 135.4 million tons from 38.5 million hectares. For the 2022/23 growing season, Brazilian production was estimated at 150.36 million tons cultivated over approximately 42.4 million hectares (CONAB, 2022).

Despite its high productive potential, water availability remains one of the main limiting factors affecting soybean development and grain yield. In recent years, prolonged drought events have become increasingly frequent in several producing regions, causing significant reductions in crop productivity and highlighting the need for technologies capable of improving plant tolerance to water deficit.

Among the sustainable strategies currently under investigation, the use of plant growth-promoting rhizobacteria (PGPR) has attracted considerable attention due to their ability to establish beneficial associations with plant roots and induce physiological changes that enhance plant growth. These bacteria stimulate root development, increasing the volume of soil explored by the root system and, consequently, improving water and nutrient uptake, thereby contributing to greater plant tolerance under adverse environmental conditions.

Promising results have been reported for several species of the genus *Bacillus*. In a study involving bacterial isolates obtained from the rhizosphere of cactus species native to the Caatinga biome, maize plants inoculated with *Bacillus* spp. exhibited a 28.2% increase in growth under water deficit conditions,

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demonstrating the potential of these bacteria to mitigate the adverse effects of drought stress (KAVAMURA, 2013).

Among the species of agricultural interest, *Bacillus aryabhattai* has emerged as a promising plant growth-promoting bacterium. Scanning electron microscopy studies have demonstrated its ability to colonize soybean tissues, establishing a symbiotic interaction capable of modulating the expression of genes associated with the synthesis and stability of plant phytohormones, thereby promoting plant growth and development (PARK et al., 2017).

Based on these findings, commercial products containing *Bacillus aryabhattai*, such as those formulated with strain CMAA 1363 (HOBER Aris®, Ballagro), have been developed and registered for use in maize. These products are intended to improve plant performance under water-limited conditions by enhancing water-use efficiency, strengthening both root and shoot development, and helping to preserve crop yield potential during periods of drought stress.

However, although the beneficial effects of *B. aryabhattai* have been demonstrated in other crops, information regarding its performance in soybean, particularly concerning seed seed physiological performance during germination and early plant development under water deficit conditions, remains limited.

Therefore, the present study aimed to evaluate the effects of soybean seed inoculation with *Bacillus aryabhattai* on seed seed physiological performance during germination and plant development under water deficit conditions, investigating its potential as a biotechnological tool to enhance soybean tolerance to drought stress.

## 2. MATERIALS AND METHODS

### 2.1 Experimental site and biological material

Soybean seeds of the cultivar BRASMAX ZEUS IPRO, without chemical seed treatment, were used in both experiments. Seed inoculation was performed using a commercial liquid formulation containing *Bacillus aryabhattai* strain CMAA 1363 (HOBER Aris®, Ballagro) at the recommended rate of 4 mL $kg^{-1}$ of seed. The inoculant was uniformly applied to the seeds immediately before sowing.

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### 2.2 Experiment I: Plant growth under water deficit

The first experiment was conducted to evaluate the effects of *Bacillus aryabhattai* inoculation on soybean development under water deficit conditions.

The experiment was performed in 5-L plastic pots filled with a dystrophic Red Latosol collected from the experimental area of UTFPR and covered with a 1-cm layer of commercial substrate to facilitate seedling emergence.

The experimental design was completely randomized in a 2 × 2 factorial arrangement, consisting of two factors:

- Seed inoculation with *Bacillus aryabhattai* (with or without inoculation);
- Water availability (with or without water deficit).

Four treatments were established:

- IB – inoculated plants under adequate irrigation;
- IA – inoculated plants subjected to water deficit;
- SB – non-inoculated plants under adequate irrigation;
- SA – non-inoculated plants subjected to water deficit.

Each treatment consisted of five biological replicates, with one pot considered as the experimental unit. Four seeds were sown per pot, and after seedling establishment, thinning was performed, leaving two plants per pot.

Plants were grown under natural environmental conditions with irrigation supplied according to crop requirements until the beginning of the stress period. Basal fertilization consisted of 3 g of NPK fertilizer (4–14–8) per pot.

Water deficit was imposed 46 days after sowing by completely withholding irrigation for 23 consecutive days in the IA and SA treatments. After this period, irrigation was resumed until the end of the experiment, totaling 77 days of cultivation.

At harvest, plants were carefully removed from the pots, and the root systems were washed with running water to remove soil particles without damaging the roots.

The following variables were determined:

- Shoot length (cm);
- Root length (cm);

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- Shoot fresh biomass (g);
- Root fresh biomass (g);
- Shoot dry biomass (g);
- Root dry biomass (g).

Dry biomass was determined after drying the samples in a forced-air circulation oven at 65°C until constant weight.

### 2.3 Experiment II: Seed seed physiological performance during germination

The second experiment evaluated the influence of seed inoculation with *Bacillus aryabhattai* on soybean seed physiological performance during germination.

The experiment was carried out in the Seed Analysis Laboratory of UTFPR using the paper roll germination test.

Approximately 500 g of soybean seeds were inoculated with *B. aryabhattai* at the same application rate used in Experiment I. The control treatment consisted of non-inoculated seeds.

The experimental design was completely randomized with two treatments:

- inoculated seeds;
- non-inoculated seeds.

Each treatment consisted of four replicates of 50 seeds, totaling 400 seeds per treatment.

Seeds were placed on Germitest® paper towels previously moistened with distilled water equivalent to 2.5 times the dry paper weight. The paper sheets were rolled, packed inside polyethylene bags to prevent moisture loss, and incubated in a Mangelsdorf-type germination chamber maintained at 25°C under a 12-h photoperiod.

To simulate a more restrictive condition during seedling establishment, the paper rolls were not rehydrated throughout the eight-day incubation period.

After eight days, the following variables were evaluated:

- Germination percentage;
- Percentage of abnormal seedlings;

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- Shoot fresh biomass;
- Root fresh biomass;
- Shoot dry biomass;
- Root dry biomass.

Fresh biomass was determined immediately after seedling evaluation. Subsequently, shoot and root tissues were dried in a forced-air oven at 65°C until constant weight for dry biomass determination.

### 2.4 Statistical analysis

Data from both experiments were subjected to tests of normality prior to statistical analysis. Analysis of variance (ANOVA) was performed using a significance level of 5%. When significant effects were detected by the F-test ($P \leq 0.05$), treatment means were compared using Tukey's multiple comparison test at the 5% probability level. All statistical analyses were performed using the R statistical software (RStudio®).

## 3. RESULTS AND DISCUSSION

### 3.1 Shoot growth of soybean plants under water déficit

Soybean seed inoculation with *Bacillus aryabhattai* significantly influenced shoot development under both irrigated and water-deficit conditions (Figure 1). Among the evaluated treatments, inoculated plants maintained under adequate irrigation (IB) exhibited the greatest shoot length, fresh biomass, and dry biomass, demonstrating the growth-promoting effect of the bacterium even in the absence of abiotic stress.

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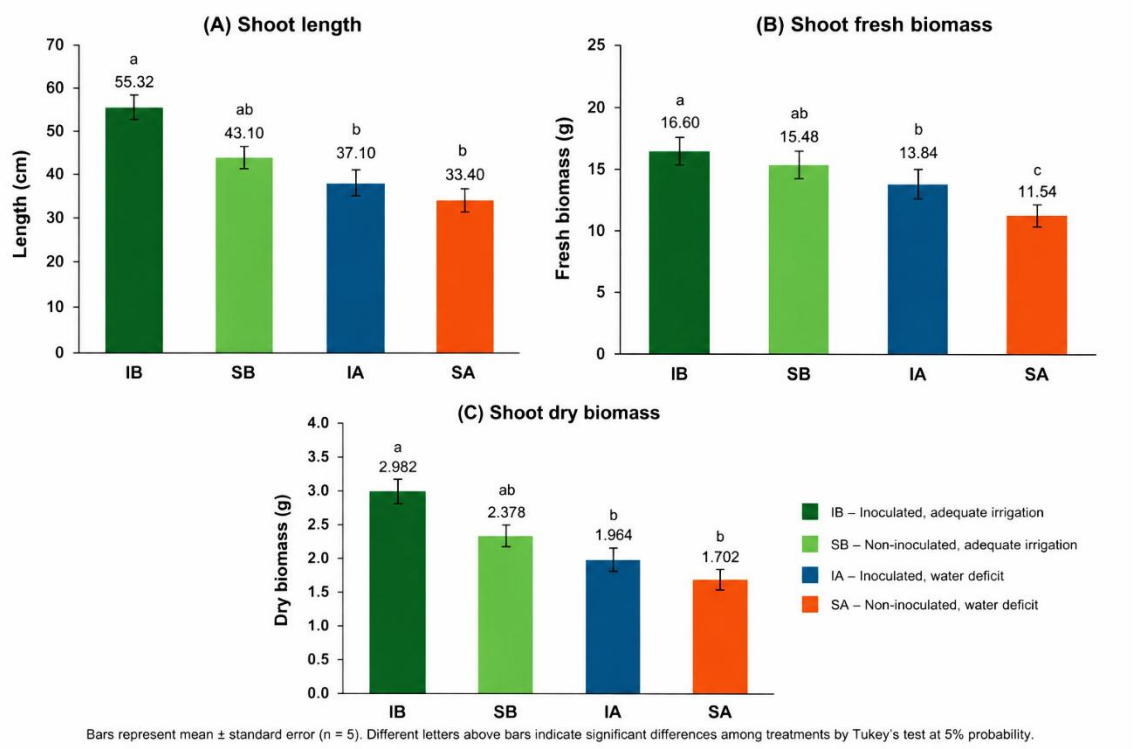
**Figure 1.** Shoot growth of soybean plants inoculated or not with *Bacillus aryabhattai* and grown under adequate irrigation or water deficit conditions. (A) Shoot length (cm), (B) shoot fresh biomass (g), and (C) shoot dry biomass (g). Treatments: IB = inoculated plants under adequate irrigation; SB = non-inoculated plants under adequate irrigation; IA = inoculated plants under water deficit; SA = non-inoculated plants under water deficit. Bars represent treatment means (n = 5), and different letters above the bars indicate significant differences among treatments according to Tukey's test at the 5% probability level (P ≤ 0.05). Error bars represent the standard error of the mean.




Source: The authors.

Water restriction reduced all shoot growth variables; however, inoculated plants subjected to water deficit (IA) showed superior performance compared with non-inoculated plants exposed to the same stress condition (SA). Shoot length increased from 33.4 cm in SA to 37.1 cm in IA, while shoot fresh biomass increased from 11.54 g to 13.84 g. Likewise, shoot dry biomass increased from 1.702 g in non-inoculated plants to 1.964 g in inoculated plants (Figure 1). These results indicate that *B. aryabhattai* partially alleviated the detrimental effects of drought stress on soybean growth.

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The superiority observed in inoculated treatments demonstrates the beneficial interaction established between the bacterium and soybean plants. The increase in shoot biomass suggests greater water-use efficiency and improved physiological performance during vegetative development. Similar results were reported by NDOUNG (2019), who observed increased stem diameter and shoot height in maize plants inoculated with *Bacillus aryabhattai* under water-deficit conditions. According to these authors, drought stress triggers bacterial production of phytohormones such as indole-3-acetic acid (IAA), abscisic acid, and gibberellins, promoting plant growth even under unfavorable environmental conditions.

Furthermore, PARK et al. (2017) demonstrated that *B. aryabhattai* colonizes soybean tissues and modulates the expression of genes associated with phytohormone synthesis and homeostasis, contributing to improved plant growth and greater tolerance to abiotic stress.

Visual observations performed throughout the experiment corroborated the biometric results. Plants from the SA treatment showed earlier wilting symptoms and greater reduction in vegetative growth than inoculated plants subjected to water deficit, reinforcing the beneficial role of *B. aryabhattai* in maintaining plant development during prolonged periods of water restriction.

### 3.2 Root development under water deficit

Root growth responded positively to seed inoculation with *Bacillus aryabhattai* (Figure 2). The IB treatment presented the highest values for root length, fresh biomass, and dry biomass, followed closely by the IA treatment. Notably, inoculated plants subjected to water deficit exhibited root growth statistically similar to irrigated inoculated plants for root length and fresh biomass, indicating that bacterial inoculation minimized the negative impact of drought on root development.

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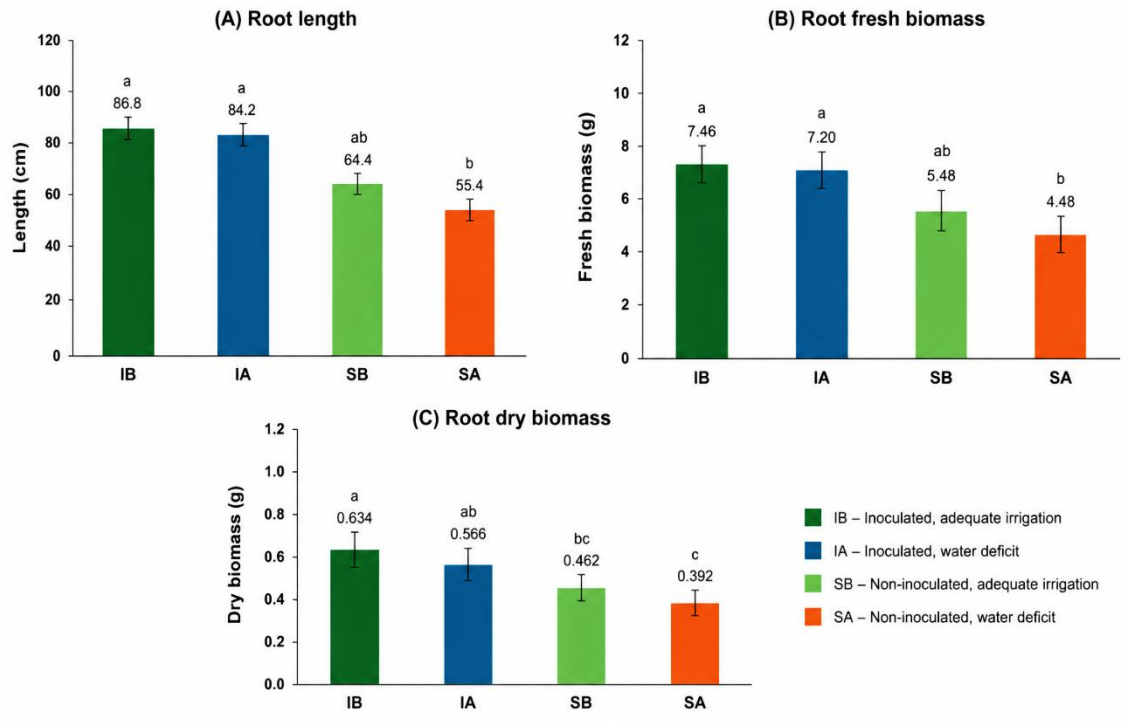
**Figure 2.** Root development of soybean plants inoculated or not with *Bacillus aryabhattai* and grown under adequate irrigation or water deficit conditions. (A) Root length (cm), (B) root fresh biomass (g), and (C) root dry biomass (g). Treatments: IB = inoculated plants under adequate irrigation; IA = inoculated plants under water deficit; SB = non-inoculated plants under adequate irrigation; SA = non-inoculated plants under water deficit. Bars represent treatment means (n = 5), and different letters above the bars indicate significant differences among treatments according to Tukey's test at the 5% probability level ($P \leq 0.05$). Error bars represent the standard error of the mean.




Source: The authors.

The IA treatment produced roots averaging 84.2 cm in length, whereas non-inoculated plants under water deficit (SA) reached only 55.4 cm. Similar responses were observed for fresh and dry root biomass, with inoculated plants consistently outperforming non-inoculated plants under stress (Figure 2).

The enhanced root development observed in inoculated plants represents an important adaptive mechanism under drought conditions, since a more extensive root system increases soil exploration and improves water uptake. Consequently, improved root architecture may contribute directly to maintaining shoot growth during periods of limited water availability.

PARK et al. (2017) also reported significant increases in root development and shoot growth in soybean and rice plants inoculated with *B. aryabhattai*, demonstrating the ability of this bacterium to regulate plant metabolism under stress

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conditions. Likewise, LEE, KA and SONG (2012) observed increases of up to 121.1% in root length following inoculation with *B. aryabhattai*, suggesting that this rhizobacterium represents an environmentally sustainable alternative for improving plant establishment in water-limited environments.

Taken together, the shoot and root responses observed in the present study demonstrate that inoculation with *B. aryabhattai* promotes a more vigorous plant architecture, allowing soybean plants to better withstand prolonged periods of water deficit.

### 3.3 Seed physiological performance during germination of soybean seedlings

Seed inoculation with *Bacillus aryabhattai* also influenced the early development of soybean seedlings (Figure 3). Although germination percentage remained high in both treatments (99.9% in inoculated seeds and 100% in non-inoculated seeds), inoculated seedlings accumulated significantly greater shoot fresh and dry biomass than non-inoculated seedlings.

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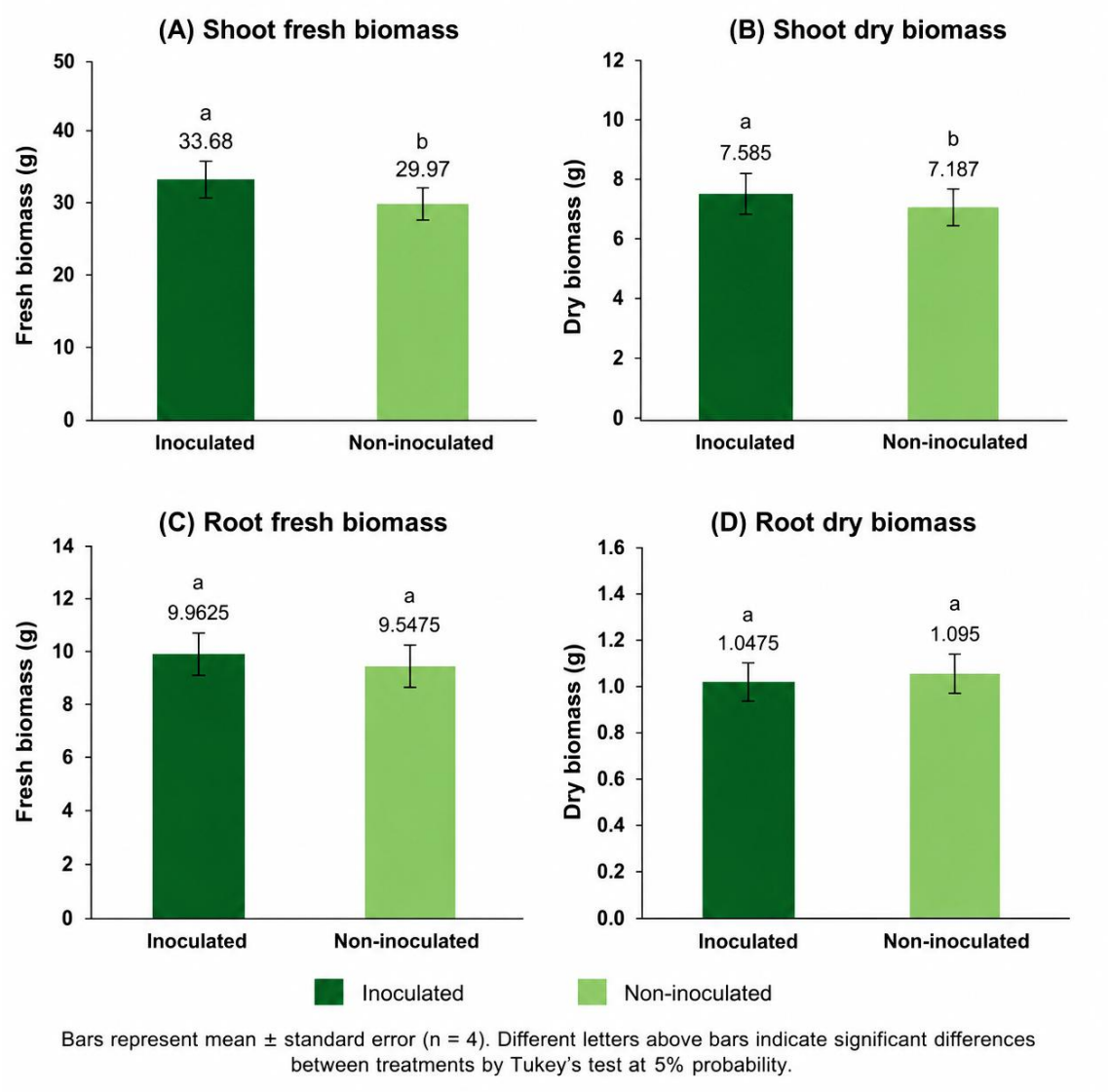
**Figure 3.** Fresh and dry biomass of soybean seedlings obtained from seeds inoculated or not with *Bacillus aryabhattai*. (A) Shoot fresh biomass (g), (B) shoot dry biomass (g), (C) root fresh biomass (g), and (D) root dry biomass (g). Treatments consisted of inoculated and non-inoculated seeds. Bars represent treatment means (n = 4). Different letters above the bars indicate significant differences according to Tukey's test at the 5% probability level (P ≤ 0.05). For root fresh and dry biomass, no significant differences were detected between treatments, and both means belong to the same statistical group. Error bars represent the standard error of the mean.




Source: The authors.

Shoot fresh biomass increased from 29.97 g in the control treatment to 33.68 g following inoculation, while shoot dry biomass increased from 7.187 g to 7.585 g (Figure 3). These results indicate that bacterial inoculation stimulated seedling vigor by promoting greater tissue accumulation during the initial stages of development.

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In contrast, no significant differences were detected for root fresh or dry biomass (Figure 3), indicating that the beneficial effects of *B. aryabhattai* during germination were primarily associated with shoot development rather than root biomass accumulation. Nevertheless, the numerical superiority observed in root fresh biomass suggests a positive tendency that could become more evident during later developmental stages.

The absence of differences in germination percentage demonstrates that inoculation did not affect seed viability, whereas the increased biomass accumulation indicates enhanced physiological performance immediately after germination. Such responses are particularly important because vigorous seedlings generally establish more rapidly in the field and exhibit greater tolerance to subsequent environmental stresses.

Overall, the results obtained in both experiments consistently demonstrate the plant growth-promoting capacity of *Bacillus aryabhattai*. Improvements in shoot growth, root development, and early biomass accumulation suggest that this bacterium enhances soybean physiological performance and contributes to greater tolerance to water deficit, reinforcing its potential for sustainable agricultural production.

### 3.4 Graphical synthesis of the main findings

Figure 4 summarizes the principal findings obtained in this study and illustrates the proposed biological effects of soybean seed inoculation with *Bacillus aryabhattai*. The graphical synthesis integrates the responses observed throughout the experiments, highlighting the positive influence of the bacterium on plant growth, drought tolerance, seedling vigor, and root development.

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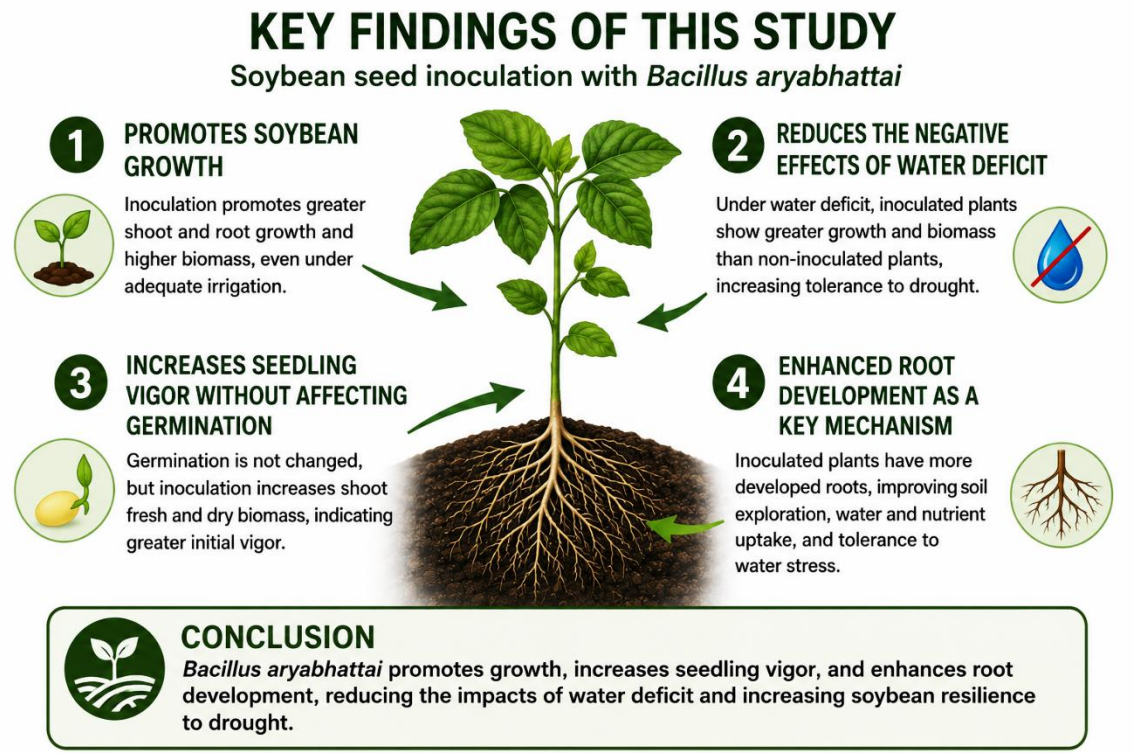
**Figure 4.** Conceptual graphical summary illustrating the main effects of soybean seed inoculation with *Bacillus aryabhattai*. The schematic integrates the principal findings obtained in this study, highlighting growth promotion, improved seedling vigor, enhanced root development, and increased tolerance to water deficit. The figure represents a conceptual synthesis based on the experimental results presented in Figures 1–3.




**Source:** Prepared by the authors with the assistance of OpenAI ChatGPT (GPT-5.5) based on the experimental results obtained in this study.

The results demonstrated that *B. aryabhattai* consistently promoted soybean growth under both adequate irrigation and water-deficit conditions. Under drought stress, inoculated plants maintained greater shoot and root development than non-inoculated plants, indicating that bacterial inoculation partially mitigated the adverse effects of water limitation. These responses are consistent with the biometric variables presented in Figures 1 and 2, which showed higher shoot and root biomass accumulation in inoculated plants.

The second important outcome summarized in Figure 4 concerns seed physiological performance. Although seed inoculation did not affect germination percentage, seedlings originating from inoculated seeds accumulated greater shoot biomass during the early stages of development (Figure 3), indicating enhanced

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initial vigor. Increased seedling vigor may contribute to faster crop establishment and greater tolerance to subsequent environmental stresses.

Another relevant finding illustrated in Figure 4 is the marked stimulation of root development promoted by *B. aryabhattai*. A larger and more vigorous root system increases soil exploration, water uptake, and nutrient acquisition, representing one of the most plausible mechanisms responsible for the improved tolerance of inoculated soybean plants to water deficit.

Overall, the conceptual model presented in Figure 4 integrates the experimental evidence obtained in this study and demonstrates that seed inoculation with *Bacillus aryabhattai* represents a promising biological strategy to improve soybean growth and increase crop resilience under drought conditions.

## 4. CONCLUSION

Seed inoculation with *Bacillus aryabhattai* promoted soybean growth under the experimental conditions evaluated, resulting in greater shoot and root development in comparison with non-inoculated plants. Positive effects were observed both under adequate irrigation and under the water-restriction regime adopted in this study, indicating that inoculated plants maintained higher biomass accumulation and vegetative growth during the experimental period. In addition, inoculation did not negatively affect seed germination and was associated with greater shoot biomass accumulation during the early stages of seedling development, suggesting a beneficial effect on initial plant establishment.

Under water-deficit conditions, inoculated plants exhibited superior growth compared with non-inoculated plants exposed to the same irrigation regime. These findings suggest that the growth-promoting effects of *B. aryabhattai* may contribute to reducing the impact of water restriction on early soybean development under the evaluated conditions. However, because the intensity of the water deficit was not directly quantified and no physiological, biochemical, or molecular indicators related to drought tolerance were measured, the results should not be interpreted as direct evidence of increased drought tolerance, resilience, or improved water-use efficiency.

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The present study represents an important initial assessment of the potential of *B. aryabhattai* as a soybean seed inoculant, demonstrating its capacity to promote plant growth and maintain plant development under contrasting water availability conditions.

Nevertheless, confirmation of its role in mitigating drought stress requires additional investigations involving the quantification of soil water status, evaluation of bacterial colonization, nodulation and plant–microorganism interactions, as well as physiological measurements, greenhouse validation, and field experiments under naturally occurring water-limited conditions. Such studies will be essential to clarify the mechanisms involved and to determine the practical agronomic applicability of this microorganism for soybean production under drought-prone environments.

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## REFERÊNCIAS

**COMPANHIA NACIONAL DE ABASTECIMENTO (CONAB).** Acompanhamento da safra brasileira de grãos. Brasília, DF: CONAB, 2017.

**COMPANHIA NACIONAL DE ABASTECIMENTO (CONAB).** Acompanhamento da safra brasileira de grãos: safra 2022/23. Brasília, DF: CONAB, 2022.

**EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA (EMBRAPA SOJA).** Soja em números (safra 2020/2021). Londrina: Embrapa Soja, 2021.

**HIRAKURI, Marcelo Hiroshi; LAZZAROTTO, Joelsio José.** *O agronegócio da soja nos contextos mundial e brasileiro*. Londrina: Embrapa Soja, 2014. (Documentos, 349).

**KAVAMURA, V. N.; SANTOS, S. N.; SILVA, J. L.; PARMA, M. M.; ÁVILA, L. A.; VISCONTI, A.; ZUCCHI, T. D.; TAKETANI, R. G.; ANDREOTE, F. D.; MELO, I. S.** Screening of Brazilian cacti rhizobacteria for plant growth promotion under drought. *Microbiological Research*, v. 168, n. 4, p. 183–191, 2013.

**LEE, S.; KA, J. O.; SONG, H. G.** Growth promotion of *Xanthium italicum* by application of rhizobacterial isolates of *Bacillus aryabhattai* in microcosm soil. *Journal of Microbiology*, v. 50, n. 1, p. 45–49, 2012.

**NDOUNG, Ornelle Christiane Ngo et al.** *Potencial de Bacillus aryabhattai para o controle de Meloidogyne incognita na cultura do milho*. 2019.

**PARK, Y. G.; MUN, B. G.; KANG, S. M.; HUSSAIN, A.; SHAHZAD, R.; SEO, C. W.; KIM, A. Y.; LEE, S. U.; OH, K. Y.; LEE, D. Y.; LEE, I. J.** *Bacillus aryabhattai* SRB02 tolerates oxidative and nitrosative stress and promotes the growth of soybean by modulating the production of phytohormones. *PLoS ONE*, v. 12, n. 3, e0173203, 2017.

**SEDIYAMA, Tuneo.** *Tecnologias de produção e usos da soja*. Londrina: Mecenas, 2009.